Innovative cover cropping strategies to enhance soil quality in reduced-till organic production

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Intensive tillage is known to impair soil structure and accelerate decomposition, both of which have negative effects on soil health and quality. Maintaining ground cover is an essential management practice that reduces soil erosion, increases infiltration, and builds soil organic matter. For this reason, many growers now preserve ground cover through no-till management, but this has proven challenging in organic cropping systems for several reasons. Organic systems rely heavily on tillage for weed control, without which crop yields can suffer dramatically. Methods for no-till cover crop termination in organic systems are less reliable than chemical or intensive tillage approaches, and yield reductions are likely when they necessitate delayed planting or when cover crops survive termination and persist to compete with cash crops (Parr et al., 2011). Moreover, soil warming can be slowed when remaining cover crop material forms a thick surface mulch. This poses a significant obstacle for organic growers in the Upper Midwest where tillage is the primary tool used to expose and warm seedbeds (e.g., Leavitt et al., 2011). Clearly, new strategies are needed to successfully reduce tillage in Midwestern organic production.

Several stated goals of organic agriculture, such as increasing organic matter and enhancing soil biological activity, have been limited by an inadequate understanding of how to implement organic management while maintaining productivity. Organic matter and microbial activity are strongly linked properties that are representative of soil health in agroecosystems. Cover cropping and maintaining ground cover are fundamental components of organic systems that build both passive and active organic matter pools, increase aggregation, and enhance soil adsorption and water holding capacities. These qualities enable diverse soil microbial communities to function in dynamic roles of decomposers, nutrient cyclers, and mediators of ecosystem services. In organic production where synthetic inputs are prohibited, the proper functioning of soil systems hinges on microorganisms and soil quality. Improving soil quality in organic agriculture will require reductions in tillage, ground cover maintenance, and improvements in fertility management, all of which may be achieved through strip tillage.

Strip tillage is an attractive middle ground between intensive tillage and no tillage that involves tilling only the narrow row areas where crops will be planted, maintaining the benefits of ground cover in interrow areas. Moreover, when legume cover crops are used, residue incorporation in the strip provides readily mineralizable N for subsequent cash crops. In a system using winter annual cover crops, strip tillage first terminates the cover crop by mowing or roller-crimping, and then creates strips in the decomposing mulch via tillage. Strip tillage can also be used in a living mulch system, wherein row areas are tilled and living perennial interrow vegetation is maintained. Benefits of living mulches are much like those of winter cover crops and include protecting soil from erosion by covering the soil surface, outcompeting and suppressing weeds, reducing subsurface nutrient losses through assimilation, and finally, with a leguminous mulch, supplying mineralizable N where incorporated along rows. Moreover, living mulches are often considered a means of biological intensification (Ochsner et al., 2010), furthering their suitability for organic agriculture's emphasis on biological diversity. Still, the use of living mulches and strip tillage these remain largely neglected avenues for organic systems improvements.

Most strip tillage research to date has been conducted in conventional systems where the cover crop or living mulch is suppressed with glyphosate, and yield or nitrate losses are assessed (Ochsner et al., 2010; Qi et al., 2011b; Sawyer et al., 2010). Though it has clear potential to overcome several obstacles faced by organic growers, such as delayed soil warming (Leavitt et al., 2011) and high weed pressure, few studies have examined it in organic production (Delate et al., 2008; Leavitt et al., 2011; Lowry, 2013). Living mulches have also been an underutilized resource in organic cropping systems. Zemenchik et al. (2000) reported that kura clover, a perennial legume, is a suitable living mulch for the long, cold winters of the Upper Midwest. Qi et al. (2011a) found kura clover had more aboveground biomass and N uptake than a rye cover crop or perennial forage system, demonstrating its potential to reduce losses and provide mineralizable N in rows. Further, leaving annual cover crops to continue growing between crops rows in order to terminate them for maximum nutrient contributions has potential to provide similarly considerable benefits to cropping systems. In the cold climate of the Upper Midwest, allowing winter annual cover crops to continue growth between cash crop rows would allow the cover crops to reach maturity and thus maximally supplement soil fertility. While competition between the mulches and crops has been observed, it is unknown how to best mechanically manage for this via tillage as well as whether the fertility inputs outweigh the negative effect of prolonged cover crop growth (Brainard et al., 2013).

The proposed research aims to utilize strip tillage in both a perennial living mulch and winter annual cover crop system with the goal of enhancing soil quality, and therefore fertility, in organic production systems. Projects will be conducted over the 2015 and 2016 growing seasons, and include: a **perennial** kura/clover/corn system at the U of MN Rosemount Research & Outreach Center, and a winter **annual** cover crop/vegetable system the U of MN St. Paul campus. The **perennial** experiment has four treatments: 1) no-till, 2) conventional strip tillage, and 3) PTO-driven rotary strip tillage, and 4) a double-till systems using both strip till + rotary strip till. This project has a random complete block design with four blocks. The objectives of this project are to determine the effect of strip tillage on: 1) corn N uptake and yield, and 2) the spatial distribution of soil labile organic matter pools across crop rows. Conventional strip tillage drags angled coulters through soil, producing a wide band (approximately 30 cm) of bare soil at the surface with a relatively narrow tilled slot 15-20 cm deep. Alternatively, rotary strip tillage produces a rectangular zone of incorporation, but of a shallower depth. We hypothesize that treatments utilizing rotary strip till will increase corn N uptake and yield, but that these treatments will show a decrease in several labile pools, like microbial biomass and particulate organic matter. Winter **annual** plots have a split-plot design, where whole plot treatments are cover crop (oat+pea and rye+vetch) and sub plot treatments are tillage (conventional and strip). Conventional tillage is tillage across the whole plot, and strip tillage only disturbs soil where plastic mulch will be laid. Both tillage treatments used plasticulture, and there are four replicates. Summer squash was used as a main crop and was direct seeded in July. The objectives of this project are to determine whether leaving cover crops to mature between rows (strip till): 1) increases soil fertility contributions, and 2) increases soil quality in rows and/or between rows. We hypothesize that by doing so, the cover crops will make greater nutrient contributions, and will also increase soil quality between rows for future alternate row plantings.

Cover crop biomass will be analyzed for C/N with an Elementar VarioMAX CHN Analyzer. Weeds are controlled by hand in both systems. Squash are hand harvested at maturity and yield has been recorded. Soil will be sampled from within and between row crops three times over the growing season: 1) before spring tillage, 2) 7-10 days after tillage, and 3)at crop harvest, and will be used in a variety of assays indicative of soil quality. Soils from each plot will be sampled by homogenizing 10 samples of the top 15 cm of soil and taking two sub-samples. One will be kept field-moist, sieved to 2 mm, and refrigerated at 4°C until both microbial biomass C/N (simulated chloroform slurry extraction, adapted from Drinkwater Lab, pers. comm.) and potentially mineralizable nitrogen (PMN; adapted from McSwiney et al., 2010) are measured within two weeks of collection. The other sub-sample will be dried at 35°C, sieved to 2 mm, and used for several assays: 1) total organic C and total N (TOC/TN), 2) potassium permanganate oxidizable carbon (POX-C; adapted from Weil et al., 2003), and 3) light-fraction particulate organic matter C/N (POM; Marriott & Wander, 2006). These analyses have been chosen to reflect microbial activity and soil quality. Statistical analyses for differences between treatments and row/interrow areas will be conducted using SAS software (Cary, NC). Results will enable organic growers to maximize cover crop advantages as ground cover and fertility sources, as well as conserve soil structure, tighten the N cycle, and reducing environmental pollution.

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